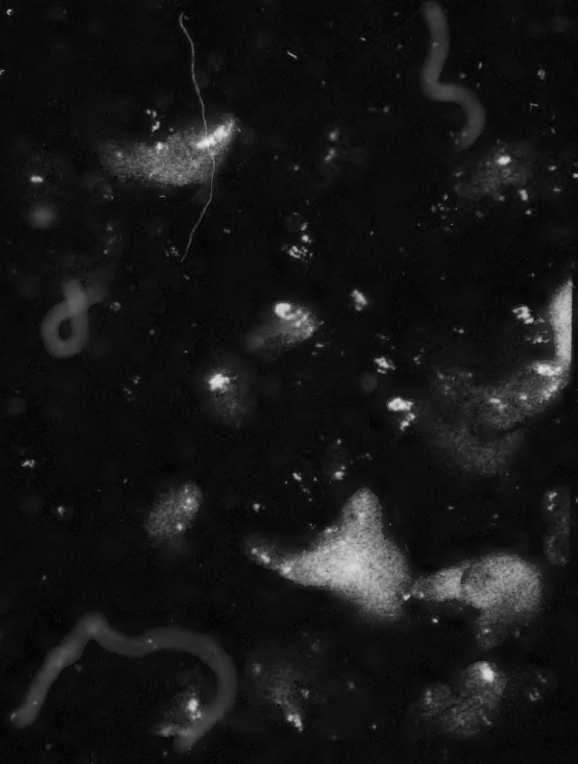
NRC·CNRC

Plant Biotechnology Institute

Annual Report 1990/91

Biotechnology



Canada

The National Research Council

The National Research Council of Canada (NRC) is the premier science and engineering organization of the Government of Canada. In 1990/91, it had an annual budget of roughly 400 million dollars and more than 3,000 employees working in research institutes and a variety of programs and facilities across the country. NRC accounts for about 10% of federal expenditures on science and technology, and provides technical advice and assistance to more than 500,000 Canadians annually.

NRC serves the needs of Canadians by helping to maintain and enhance the prosperity and competitiveness of the country through:

- the support of national science and engineering activities;
- the performance of research and development;
- the stimulation of investment in research and development; and
- the development and provision of vital expertise and knowledge.

To this end, NRC is both responsive and flexible, achieving its goals in partnership with others, including industry, universities and governments.

Several fundamental corporate values sustain NRC and the activities it carries out and supports:

- NRC is committed to excellence and will maintain the highest possible standards in its work;
- NRC values its employees and has an historical dedication to staff excellence. It has one of the most highly qualified and experienced work forces in Canada;
- NRC values innovation and strongly supports the pursuit of new developments that can improve Canada's social and economic well-being and competitiveness;
- NRC values its partners and clients and knows that Canadians expect it to provide solutions to problems that have not been solved elsewhere;
- NRC is committed to service to the public;
- NRC supports accountability and performs its responsibilities in a manner which constantly ensures that Canada's investments in science and technology are yielding the highest national benefits.

The National Research Council is the Government of Canada's lead agency for biotechnology research. The Plant Biotechnology Institute is one of four NRC research centres in the NRC biotechnology program fulfilling this role. The chart on page 5 shows the overall organizational structure of NRC.

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Front: *Somatic embryos of black spruce matured on abscisic acid medium. These will grow into large numbers of genetically identical plantlets. Photo by PBI/NRC guest researcher Tom Tautorus.*

Back: *The Kristjanson Biotechnology Complex, home of PBI's Transgenic Plant Centre. Photographer: David Brown.*

Highlights of 1990/91

During 1990/91 the NRC Plant Biotechnology Institute entered its eighth year of operation, and the second under its five-year business plan. We received from NRC a new and more precise mission, made substantial changes in our activities, and entered the general review of the Biotechnology Program being carried forward by the Council in 1991. Under the new mission, our Institute focuses on:

- advancement of biotechnology research;
- generation of new transgenic plants;
- provision of facilities for industrial development;
- communication with the research community; and
- training of biotechnology personnel.

These facets all showed good progress in 1990/91, and the Institute was able to increase its partnerships and its leverage of R&D investment in Canada, notwithstanding the general economic recession and the depressed condition of the agricultural sector in Canada.

The Research Program

Our focus on **transgenic technology** continued throughout the year. Specimens of species never genetically transformed previously were produced this year in our laboratories. Strawberry plants and pea plants carrying inserted drug resistance genes as "markers" were engineered, by different methods; these were world firsts for the Institute. Cells of wheat, barley and the oilseed crop *Brassica juncea* were also newly transformed but complete plants have not yet been regenerated from these.

Improved performances by transgenic plant specimens transformed with novel and useful genes, were achieved in our greenhouses with tobacco and *Arabidopsis* (model systems), and with canola, *Brassica napus* (insect resistance). Two systems of herbicide-resisting *B. napus* plants were successfully field-tested in 1990, one as a development within our own program and the other coming arising from the work of one of our industrial partners and targeted on different herbicide biochemistry.

Advances in gene technology research included the discovery of new promoter search methods of general applicability in plants and other organisms; this was a very important step forward for PBI as it leads directly into one of the priority areas of our five-year plan — gene expression control systems. Our scientists found DNA regulatory elements allowing tissue-specific expression in plants, demonstrating more than a dozen examples. And we also examined several gene expression tools specific for developmental stages of plants. The search for and identification of novel useful genes continued apace. Among agronomically useful genes, detailed identification of genes conferring salt stress tolerance in organisms was completed, and further progress was made in the area of anti-freeze genes. Among genes encoding for value-added characteristics, our work with a few key genes for fatty acid modification was notable.

Other **research advances** included new techniques for insertion and detection of foreign DNA into plant cells; and improved protocols for regenerating plant cells into entire plants via such means as embryogenesis.

More than 120 research articles, poster presentations and presented papers emanated from the Institute during the year, informing the science and technology community of advances made in our laboratories. Our scientific staff participated in more than a hundred national and international conferences and symposia.

The Technology Development Program

PBI's **partnerships** expanded notably in number and in scale. A large and long-term partnership with Hoechst Canada Inc. was established for research and development valued at more than $3 million over four years. A joint research effort of similar size and duration in conifer tree micropropagation continued into its second year with BC Research Corporation. Partner organizations funded salaries of dozens of laboratory guests, contributing 58 person-years of labour to the research effort at the Institute, at an estimated value of $3.5 million. More than half of these guests were members of industrial research teams located in the Institute, with the remainder comprised mostly of university graduate students.

Facilities newly provided or expanded during the year included the Transgenic Plant Centre which came to full technical strength and full occupancy by the end of its first year of operation in February 1991. At the Institute's main building only one laboratory was renovated but two new cell growth units were added to the existing array. The Technology Development Office set up at the beginning of the year enabled the Institute to process and promote NRC's business in plant biotechnology more effectively than before, and this move was welcomed by clients and collaborators alike.

In October 1990 the Institute organized and hosted a national workshop on seed oil modification which drew more than one hundred participants. The year was particularly fruitful in the signing of an NRC-Forestry Canada memorandum of understanding and in its follow-up through joint planning and collaboration. Our communication links with other federal and provincial agencies were also improved.

Training of personnel for Canada's biotechnology industries remained an important role of PBI. Ninety-four people from academia, public organizations and industries received three months or more of laboratory training at PBI in 1990/91. More than one-third of these were students in graduate programs at Canadian universities, who used the facilities of PBI for their thesis research, with most of the remaining two-thirds being industry personnel. Through seminars and small workshop activities on our premises, a further 2000 people received some form of direct knowledge upgrading in plant biotechnology. More than half a dozen companies have now established their research teams in our premises to take advantage of the facilities and training offered by the Institute.

The Institute's operational expenditures apart from salaries amounted to $3.9 million in 1990/91, including $0.2 million in revenues earned through cost-recovery services. For new equipment, $0.7 million was expended, and the PBI paylist cost for the year was close to $6.0 million. Our partners invested approximately $4.2 million dollars in research operations on our premises, equivalent to 40% of NRC's own on-site investment. This was the highest level of extramural investment ever attained at PBI, and is a large step forward in NRC's plans to increase its Institutes' impact on R&D investment generally in Canada.

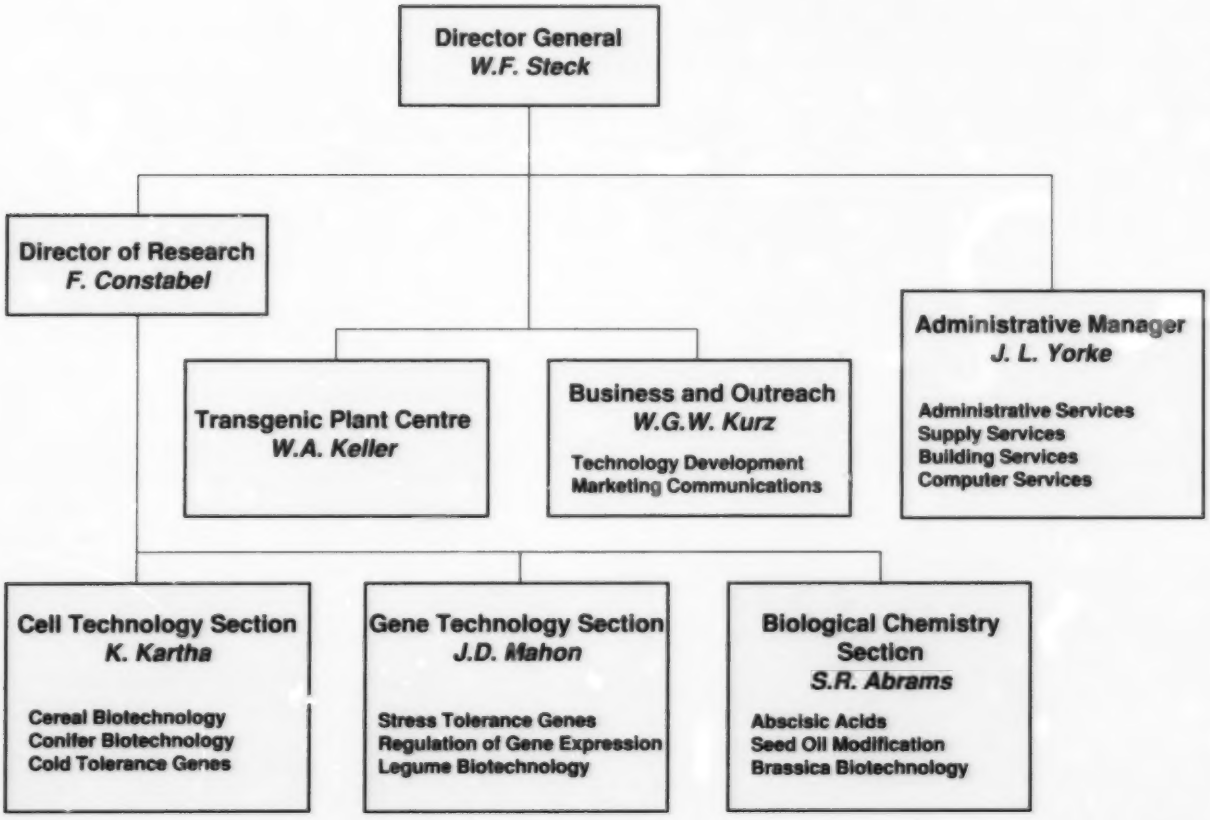
Warren Steck

Warren Steck
Director General

Organization and Mission

The structure of the National Research Council in 1990/91 is shown in the chart on the opposite page. The Plant Biotechnology Institute is one of the sixteen research centres operated across Canada by NRC, and is part of the Council's program in biotechnology. The organization of our Institute is shown in the diagram below.

The Organization of the NRC
Plant Botechnology Institute in 1990/91



The National Research Council has given the Plant Biotechnology Institute this mission:

"The Plant Biotechnology Institute (PBI) is committed to the mission of the National Research Council in serving the needs of Canadians by helping to maintain and enhance the economic and social well-being of the country.

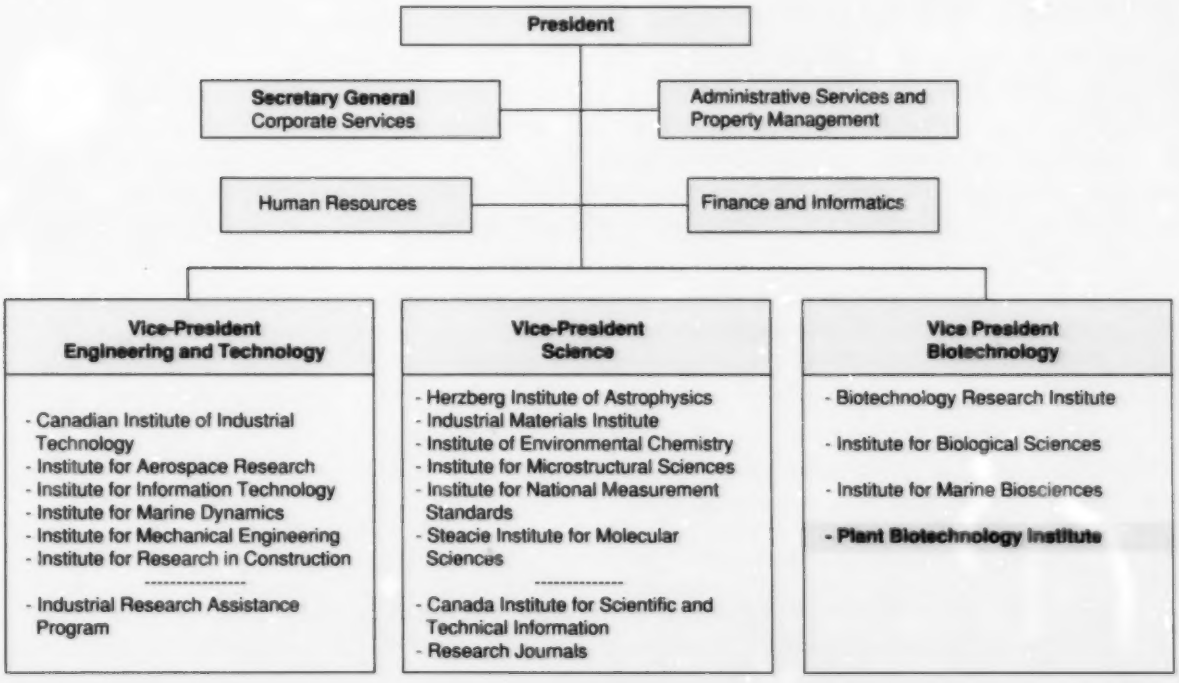
"The mission of the Plant Biotechnology Institute is to promote, assist and undertake, in partnership with industry, academia and government departments, research and development in plant biotechnology aimed at delivering economic and social benefits for Canada in agriculture, forestry and plant industries.

"To fulfil this mission PBI will, in partnership with industry, universities and public sector groups:

- undertake biotechnology research aimed at producing novel crop and forest plants;
- operate major facilities and generate enabling technologies for the testing and exploitation of novel plants;
- advance research in plant biotechnology;
- communicate and transfer new discoveries in plant biotechnology to all scientific sectors;
- provide training of highly qualified personnel in the field of plant biotechnology;

"The effectiveness of the Plant Biotechnology Institute will be assessed on the basis of the quality and relevance of its research and development activities and outputs and its interactions with clients and partners."

National Research Council Canada



Research Laboratories

Director of Research: Dr Friedrich Constabel

The Institute's research in seed plant biotechnology is based on generic, pre-competitive projects whose outputs help other organizations to undertake development or commercialization activities important for Canada. Besides NRC's own core generic research, we performed an increased level of applied research and development in 1990/91 through business partnerships. Currently PBI's research focuses on two broad themes:

- generation of novel transgenic (genetically engineered) plants potentially useful in Canadian agriculture, industry or forestry; and
- identification and regulation of genes useful in increasing the value of Canada's plant resources.

In 1990/91 groups continued to work mainly with four important Canadian plant types: the cereal grains wheat and barley, the grain legumes, members of the genus *Brassica*, and spruces and pines among the conifer trees. During the year, PBI groups generated transgenic pea plants, transgenic wheat cells, and transgenic spruce cells. Our ability to transform and regenerate *Brassica* was extended to new crop species in this genus. Through research partnerships, many other novel plant types were also produced in our laboratories.

Some projects were concerned with useful genes, gene regulatory elements and gene products, for alteration of plant traits. These projects dealt with abscisic acid hormones, with cold tolerance in plants, with tolerance to environmental stresses, with genes for modification of seed oils, and with gene regulation itself in plants. The Institute also maintained laboratory service units in mass spectroscopy, nuclear magnetic resonance spectroscopy, and for DNA strand synthesis, amplification and sequencing, which served not only the internal NRC program but also a large number of external clients and collaborators via fee-for-service arrangements. This year the Institute established a new facility for protein microsequencing which complements capabilities in other NRC biotechnology Institutes.

Our laboratories continue to be a training ground for students in plant biotechnology through arrangements with Canadian universities, and for industry personnel through the Guest Research program and a new Technology Development Laboratories initiative. This year more than one hundred people received in-depth training at our Institute.

PBI's projects are described briefly in the following pages, and a comprehensive list of our staff's research publications in 1990 appears on pages 22 to 25.

Cereal Grains Biotechnology

Project staff

Research Officers:
Drs Kutty K. Kartha (project leader), Ravindra Chibbar, Kuo-Nan Kao
Technical Officers:
Karen Caswell, David Horn, Nick Leung, Cliff Mallard, Morris Michayluk, Keith Pahl, Lee Steinhauer
Research Associates:
Drs Edward Kendall and Narender Nehra
Guest Researchers:
Robert Adams, Darryl Arsenault, Perry Aulie, Allison Baillie, Darrel Hamm, Grace Johnson, Linda McGregor, Y. Niu, Brian Orshinsky, Brian Weir, Linda Wong, Huacheng Wu, Guohai Wu, Jing Yi Yang, Ming Ye

The aim of this group is to advance the biotechnology of wheat and barley, and particularly to develop transgenic forms of these cereals.

Research in 1990/91

Genetic engineering of wheat and barley:
Research on the genetic transformation of wheat and barley using microprojectile bombardment progressed to conclusive demonstration of transient expression of several marker genes introduced into diverse recipient systems (such as immature zygotic embryos, haploid calli, and cell suspension cultures). Parameters for gene delivery were standardized.

During 1990/91, research focused on achieving stable transformation using selectable marker genes. Since the most commonly used selectable marker, kanamycin, is inadequate for monocots which include cereals, constructs carrying hygromycin phosphoryltransferase (*hph*) which when expressed confers resistance to hygromycin, and the *bar* gene (bialaphos resistance), were assembled in-house and introduced into immature zygotic embryos of wheat and cell suspension cultures of barley. Putatively-transformed cells of both wheat and barley were isolated following stringent selection. Some of these exhibited hygromycin phosphoryltransferase activity indicating *hph* gene expression. Southern analyses showed one clone with an internal fragment (1200 bp) of the gene indicative of stable transformation.

Wheat seeds were multiplied over three generations from previously cryoselected spring wheat lines which had exhibited enhanced freezing tolerance to -12°C. We subjected the seedlings from the third generation to controlled freezing tests, and found that freezing tolerance selected through cryoselection was stably inherited. Several lines survived freezing even down to -15°C.

Anther and microspore culture of barley:
We can now obtain green microspore-derived plants from any lines or varieties of barley including 'Bonanza' which a few years ago produced only albinos. Up to 13 green plants from a single anther could be produced. Consequently, a large number of microspore-derived plants from different F1 hybrids and varieties have been produced for breeders at the Crop Development Centre, University of Saskatchewan, for potential incorporation into their barley improvement programs.

Partnerships in 1990/91

The Saskatchewan Wheat Pool continued to be a major collaborator. Under a joint-research agreement, the Pool provided plant breeding expertise and field testing facilities for evaluating material generated from PBI's core program on wheat biotechnology. Additionally, under the terms of an IRAP agreement, the Pool carried out a biotechnology program in our laboratories to develop haploidy systems for its wheat improvement program.

During 1990, the Western Grains Research Foundation also became a research partner through award of a research grant of $ 36,000/year for the next 3 years. The Crop Development Centre of the University of Saskatchewan remained an active collaborator on barley haploidy. The Centre carries out extensive field evaluation of barley double haploids produced at PBI.

Conifer Biotechnology

Project staff

Research Officers:
Drs David Dunstan (project leader), Martin Lapp, Edward Tsang
Technical Officers:
Terry Bethune, Cheryl Bock, Maxine Coffey, Janet Condie
Research Associates:
Drs Sylvain Adam, Brenda McAfee, Gilles Pilate
Guest Researchers:
Robert Ashton, Robin Browne, Stephane Germain, Susan Kikcio, Debbie Lashta, Monika Lulsdorf, Marie Moore, Cheryl Tautorus, Tom Tautorus

The aim of this project is to develop and apply biotechnologies for conifer trees. The principal objectives of our group are to generate better means for "cloning" of select trees by cell methods and to develop transgenic technology for conifers.

Research in 1990/91

We investigated root induction and plantlet establishment in western white pine. Several isolates of *Agrobacterium rhizogenes* assessed on shoots propagated in vitro gave improved rooting. We examined the nature of this rooting response with *A. rhizogenes* using analyses for opine synthesis, Southern blotting and polymerase chain reaction to detect transferred DNA. Rooted shoots were successfully acclimatized and established in the greenhouse.

In somatic embryogenesis in white spruce we regulated embryo germination via abscisic acid treatments (ABA). Racemic abscisyl alcohol was a satisfactory substitute for racemic ABA, with potential for reducing aberrant embryo types. Somatic embryo suspension cultures metabolized racemic ABA rapidly. With natural (+)- ABA, they formed phaseic acid quantitatively within the 8-day culture period. With the unnatural (-)- ABA negligible phaseic acid was produced. A preparative method for the bulk extraction of phaseic acid from liquid cultures is being developed. Our research on ABA and related compounds is in collaboration with the Abscisic Acids project.

Dr. David Dunstan's Conifer Biotechnology research team. Back row: David Dunstan, Terry Bethune, Sylvain Adam, Brenda McAfee, Janet Condie, Cheryl Bock. Front row: Martin Lapp, Edward Tsang, Maxine Coffey.

We studied an ABA-inducible gene promoter to find the most efficient methods for its induction and use for isolation of stable conifer transformants. Means for transformation such as electroporation and particle bombardment were compared, and transient expression was confirmed in white spruce embryos. *Agrobacterium*-mediated transformation gave anomalous results in the selection phase, suggesting a defective gene .

Partnerships in 1990/91

Our major partner was BC Research Corporation's Forest Biotechnology Centre (see page 29), which continued a three-year collaboration (valued at $2.5 million) to develop commercially exploitable procedures for clonal propagation of spruce by tissue culture approaches. Existing partnerships with Weyerhaeuser Canada Inc., with groups at the Universities of Calgary and Saskatchewan, and with Forestry Canada researchers, continued through the year. One project team member, Dr. Tsang, spent 1990/91 in the laboratories of Dr Marc van Montagu at (Laboratorium voor Genetika) in Ghent, Belgium.

Legume Biotechnology

Project staff

Research Officers:
Drs John Mahon (project leader), Shaun Hobbs, Louise Nelson
Technical Officers:
David Baliski, Catherine DeLong, Maureen Anderson, Connie Knapp
Research Associates:
Drs Mark Jordan and Hans Rempel
Guest Researchers:
Deanne Chenier, Douglas Covert, Kent Craig, David Feindel, Sue Grayston, Colin Kindrachuk, Diane Knight, Satya Miranpuri, Isabelle Poisson, Om Rajora, Norma Ruecker, Susan Scutchings, Sharon Sprout, Chris VanKessel

The objective of this project is to promote the genetic improvement of Canadian legume crops through biotechnology. In 1990/91, work focused on new methodology for the production of transgenic pea plants.

Drs. Shaun Hobbs and Jennifer Jackson examine the successful products of their cotyledonary node regeneration system.

Research in 1990/91

With the improved cotyledonary node regeneration system developed in 1989/90, it was possible to concentrate on the transfer of foreign genes to pea cells from which new shoots can be derived. Cotyledonary nodes with the buds removed were co-cultivated or injected with suspensions of *Agrobacterium* vectors containing selection marker genes. In one of the transformed shoots, there was positive molecular evidence for the incorporation of two copies of the foreign genes into the chromosomes. This plant produced two seeds, one showing the same two copies of the transferred DNA and the other showing only one of them; plants of the next generation showed Mendelian inheritance. Thus, we succeeded in introducing foreign genes into pea tissues, in recovering a fertile transgenic plant and in demonstrating that this new genetic information is stable and heritable through at least two generations.

Other work during the year aimed at improving this new technology. To improve the identification and selection of transgenic pea tissues, new *Agrobacterium* vectors were constructed containing genes for resistance to the antibiotics hygromycin and L-phosphinothricin; an improved gene for GUS containing an intron to prevent bacterial expression; and putative virulence-enhancing sequences. These genes were combined with high-expression constitutive promoters, for testing in cell culture and in cotyledonary node explant systems.

Partnerships in 1990/91

The project carried out substantial work under NRC funding agreements with the Saskatchewan Agriculture Development Fund and MicroBio Rhizogen Inc. Throughout 1990/91, Dr Shaun Hobbs was at the John Innes Research Institute in England on an educational leave. He collaborated there with Dr. R. Casey on developing and applying new methodologies for the analysis of DNA sequences regulating pea genes.

Brassica Biotechnology

Project staff

Research Officers:
Drs Wilfred A. Keller (project leader) and Jan W. D. GrootWassink
Technical Officers:
Joe Hammerlindl, Allan Kolenovsky, Janice Schmidt, Marvin Swartz
Research Associates:
Drs Alison Baillie and Jinesh Jain
Guest Researchers:
Philippe Antoine, Brigitte Bauer-Weston, Jim Cunningham, Cathy Kuiack, Sun Lee, Laurel O'Connor

The aim of this project is to generate new biotechnologies for applications to Brassica crops.

Research in 1990/91

Gene transfer methodology in Brassicas

Six breeding lines and registered cultivars of *Brassica juncea* were obtained from Gerhard Rakow (Agriculture Canada, Saskatoon). Two of the lines responded effectively *in vitro*, giving consistently high yields of regenerated shoots from cotyledonary petiole explants. Through the modification of techniques previously developed at PBI we worked out *Agrobacterium*-mediated gene transfer technology for *Brassica juncea*. Of approximately 200 shoots selected on kanamycin, 27 were GUS positive. Confirmatory evidence for stable gene transfer came from Southern blot analyses of progeny from four of these lines.

Transgenic *Brassica napus* lines with resistance to sulfonylurea herbicides arose from collaborative research with Brian Miki (Plant Research Centre, Agriculture Canada). A vector carrying a mutant *B. napus* acetolactate synthase gene for resistance to sulfonylurea and imidazolione herbicides was used in gene transfer experiments with *B. napus* cv Westar. Ten stable transgenic lines were regenerated, and progeny from four of these lines were challenged in the greenhouse with chlorsulfuron herbicide. All lines demonstrated tolerance to the treatment but flowering time was significantly retarded in comparison with unsprayed Westar plants.

Microspore culture methodology for Brassica campestris

Low but consistent frequencies of embryogenesis were obtained in cultured microspores of four breeding lines received from Agriculture Canada. Approximately 200 plantlets were regenerated from microspore derived embryos. Based on the occurrence of male sterility, we estimated more than half of these regenerants to be haploids. Plantlets from seed derived from 10 spontaneously-doubled haploid lines were sent to be evaluated at Agriculture Canada's Saskatoon Research Station. This work was partially supported by the Canola Council of Canada.

Expression of glucosinolate syntheses genes in crucifers

Among crucifer species, *Capsella bursa-pastoris* (shepherd's purse) exhibits unusual expression of glucosinolate biosynthesis. Generally all organs appear to be biosynthetically active. However, in rosette leaves of shepherd's purse both the enzymes and the glucosinolates themselves are absent. This differential regulation offers a system for identification and isolation of regulatory genes useful for developing zero-glucosinolate *Brassicas*.

Partnerships in 1990/91

A major collaborative three-year agreement was signed with Hoechst Canada, in which our project is assisting Hoechst in the development of reliable gene transfer methodology for *Brassica* species, particularly *B. campestris* and *B. juncea*. This methodology will subsequently be employed in the genetic engineering of resistance to the Hoechst herbicide ignite in these crops. To pursue this research, Hoechst Canada recruited a group of five researchers (leader: Dr. Michael Oelck) and established its office and research premises in PBI's Transgenic Plant Centre.

Cold Tolerance Genes

Project staff

Research Officers:
Drs Adrian J. Cutler (project leader), Fawzy Georges, Mohammed Saleem
Technical Officers:
Mary Loewen, Bob Papish, Sandra Polvi
Research Associates:
Drs Joe Boothe and Jay Newsted
Guest Researchers:
Nina Desjardines, Ken Friesen, Raman Kapur, Hong Wang

The project objective is to improve the freeze hardiness of tender crops through genetic engineering. Our main current focus is on the winter flounder antifreeze protein (AFP) gene.

Research in 1990/91

For stable transformation, the AFP gene was initially inserted into an *Agrobacterium tumefaciens* vector downstream from a promoter and upstream from the ß-glucuronidase (GUS) coding sequence, to produce an AFP-GUS translational fusion. Although GUS activity facilitated detection of the AFP-GUS fusion, its large size may have reduced the efficiency of secretion. For this reason, we subsequently employed constructs containing unfused AFP sequences. Various vector "backbones" were also employed to optimize ease of handling and to improve the stability of the inserted constructs. Transgenic tobacco and *Arabidopsis thaliana* plants were produced for examination and testing.

We performed preliminary experiments on targeting the protein to the extracellular spaces in tissues, to maximise AFP activity *in planta*. Transient assays used DNA leader sequences derived from various secreted plant and fungal proteins fused with marker genes such as GUS and CAT. Promising positive results were obtained using the *Kluyveromyces lactis* killer toxin leader sequence and the pre-sequence of a tobacco anionic peroxidase.

In a search for proteins related to the flounder antifreeze protein in plants and related organ-isms, we identified a protein that cross-reacts with anti-antifreeze protein serum in the snow-mould fungus (*Coprinus psychromorbidus*). This protein has a molecular weight similar to that of the fish antifreeze protein and is produced in large quantities by the mould at 4°C. Since the snow-mould fungus grows even at sub-zero temperatures, this protein may well function as the required antifreeze factor.

Partnerships in 1990/91

Part of the antifreeze work was performed under a grant from the Saskatchewan Agriculture Development Fund (1990-93, $176,000). This work addresses the need to limit antifreeze gene expression to times of maximum frost risk so that metabolic drain is minimized in the plant. Accordingly, we began to identify genes that are preferentially expressed at low temperature in *Arabidopsis thaliana* and during the cotyledon stage of *Brassica napus*. Preliminary experiments were performed to identify proteins preferentially synthesized at these times.

Dr. Mohammed Saleem monitors protein purification.

Stress Tolerance Genes

Project staff

Research Officers:
Drs Gopalan Selvaraj (project leader) and Janet L. Taylor
Technical Officers:
Carla Barber, Ira Borgmann, Rozina Hirji
Research Associates:
Drs Luc Adam, Atta Hussain, Soledade Pedras, Greg Penner, Victor Morales
Guest Researchers:
Harindra Balyan, Lesley Boyd, Armel Gallet, Ravinder Jain, Kevin Rozwadowski, Michael Thompson, Adrienne Woytowich

The objective of this Project is to identify genes and gene products that control adaptation and tolerance to environmental stress. The knowledge derived from our studies will permit new approaches to plant improvement.

Soledade Pedras, Victor Morales, Janet Taylor and Carla Barber of the fungal molecular biology team.

Research in 1990/91

Salinity tolerance (G.S.): Some plants, animals and bacterial species accumulate non-toxic compounds (for example, glycinebetaine) to combat osmotic stress. We isolated a set of microbial genes coding for the enzymes choline oxidase and betaine aldehyde dehydrogenase (BADH); a recombinant clone encoding a plant BADH was also isolated. These represent, along with the genes isolated earlier, an ensemble of five betaine biosynthesis genes. Transgenic plants carrying one of the BADH genes were constructed and assessed for BADH expression. Our results formed the first report to be published of the isolation and characterization of a gene coding for choline oxidase.

We examined the role of glutamate metabolism, by isolating a clone encoding a *Brassica napus* glutamate dehydrogenase (GDH). The complete primary structure of this GDH was deduced by DNA sequence analysis, and gave rise to the first report on isolation of a GDH cDNA from a higher plant.

Molecular biology of plant - pathogen interactions (J.L.T.) This work examines the molecular basis of plant resistance to fungal attack; it involves studying the interactions between the blackleg causal organism *Leptosphaeria maculans* and *Brassica napus*. We examined the potential plant factors contributing to pathogen resistance such as phytoalexins and virulence factors of the fungi such as phytotoxins and phytoalexin inactivation systems at the chemical biochemical level. Earlier karyotype analyses of virulent and weakly virulent species were extended to identify chromosome-specific probes.

Partnerships in 1990/91

The work on *L. maculans* is a collaboration undertaking with Ginette Séguin-Swartz (Saskatoon Research Station, Agriculture Canada). The work on osmotolerance involved several guest researchers from the University of Saskatchewan.

Regulation of Gene Expression

Project staff

Research Officers:
Drs Sean Hemmingsen (project leader), William L. Crosby, Raju S. Datla
Technical Officers:
Diana Kneeshaw, Jacek Nowak, Gina Feist
Research Associates:
Drs Faouzi Bekkaoui, Lynn Cloney, Huacheng Wu
Guest Researchers:
Robert Bacchetto, Mohan Balasubramanian, Jean Depoisier, Basu Gantotti, Larry Holbrook, Karen Oddie, Peter Schorr

Our project aims to discover and develop means for the control and regulation of gene expression in plants, as an approach to regulating plant traits.

Research in 1990/91

Research in 1990/91 featured extensive interactions within PBI (*Brassica*, Seed Oil and Conifer groups). The primary sequence of a second member of the *B. napus* acetolactate gene (*als*) family was completed and published. In collaboration with Maurice Moloney (University of Calgary) we developed a system for the efficient complementation of *Selaginella typhimurium* mutants by a modified als1 gene product from *Brassica napus*. This system permits the ready identification of novel catalytic, regulatory and herbicide tolerance mutants of plant acetolactate synthase enzyme.

Molecular Chaperones (S.H.) . We have continued our studies of the expression of plant rubisco genes in *E. coli*, and the purification and characterization of chaperonin proteins and genes from *B. napus* .

Plant Regulatory Sequences (W.L.C., R.S.D.). We generated over 300 independent transgenic tobacco lines carrying tagged regulatory sequences, several of which were isolated. One directs gene expression predominantly in phloem; others show gene expression specific to root tips, cotyledons, embryos, xylem and endosperm. We began further characterization of these lines.

Dr. W.L. Crosby with transgenic plants generated in his laboratories.

We had previously transformed *B. napus* plants with genes encoding for insecticidal proteins of the Bt family. This year we conducted (in collaboration with Martin Erlandson, Agriculture Canada) assays of plant tolerance through toxicity against diamond back moth larvae and bertha armyworm larvae, two major pests of *Brassica*. Under greenhouse conditions three of our transgenic lines displayed enhanced toxicity/tolerance to these insects.

Partnerships in 1990/91

A large number of interactions occurred during the year with university and government laboratories. In November 1990 we began work on tagging and recovery of plant regulatory sequences useful in crop development, under contract from NeoPhyte Agritechnologies Inc. A shorter funded project on probe isolation was performed for Philom Bios Inc.

Abscisic Acids

Project staff

Research Officers:
Drs Suzanne R. Abrams (project leader) and John Balsevich
Technical Officers:
Gregory Bishop, Angela Shaw
Research Associates:
Drs Lloyd Nelson and Patricia Rose
Guest Researchers:
Garth Abrams, Larry Gusta, Cheryl Hampson, Ebba Kurz, Nancy Lamb, Bo Lei, Barry Milborrow, Martin Reaney

Our objective is to develop means to increase plant productivity by manipulating processes controlled by the plant hormone abscisic acid, (ABA) for example seed germination, transpiration and resistance to heat, cold and drought. Our research is aimed at identifying and characterizing ABA receptors, and determining which ABA substances trigger physiological responses. As well we are working on development of specifically targeted plant growth regulators for practical applications and of research tools to probe ABA action.

Research in 1990/91

In 1990/91 we synthesized glucose, galactose, and lactose esters of abscisic acid in deuterated and non-deuterated form, as analytical tools. Also, we successfully achieved the synthesis of 7',7'-difluoroabscisic acid, a suicide substrate designed to inactivate ABA catabolic enzymes. This analog substitutes fully for ABA in germination and freezing tolerance assays. We discovered and exploited several new synthetic routes to biologically active and optically active ABA molecular analogs.

The metabolite phaseic acid has been obtained by biotransformation of ABA by plant cell culturing in a collaborative effort with the PBI conifer group. A second ABA metabolite 7'-hydroxyabscisic acid has been obtained by chemical total synthesis.

Partnerships in 1990/91

The Project developed extensive collaborations with partners in industry, government and university labs. Among 1990/91 industrial collaborators were Prairie Malt Ltd. (IRAP supported project), Allelix Crop Technologies Inc., and Pioneer Hi-Bred. Government collaborators include the NRC Institute for Marine Biosciences (mass spectrometry of plant hormones) and the U.S. Department of Agriculture (dormancy in wheat, abscission in cotton). We had in addition many collaborations with university scientists including Lawrence Gusta and Malcolm Devine (Saskatchewan), Robert D. Hill (Manitoba), Barry Milborrow (New South Wales, Australia), Terence Blake (Toronto), Maurice Moloney (Calgary) and Bryan McKersie (Guelph).

PBI's ABA Project team and spectrascopy services team.

Back row : Greg Bishop, Angela Shaw, Brock Chatson, John Balsevich;
Centre row: Doug Olson, Lawrence Hogge;
Front row: Patricia Rose and Suzanne Abrams .

Seed Oil Modification

Project staff

Research Officers:
Drs Samuel L. MacKenzie (project leader), George P. Slater, David C. Taylor, Edward W. Underhill
Technical Officers:
Michael Giblin, Les Hoffman, John Magus, Darwin Reed, Don Tenaschuk
Research Associates:
Drs Ljerka Kunst and Lawrence Thomson
Guest Researchers:
Raymond Dechamp, Malcolm Devine, George Haughn, Apostolos Karoutis, Marilyn Martin, Jacek ,Nowak, Kenneth Pivnick, Dubravka Rasol, David Williams

Our goal is to transform *Brassica napus* L to produce trierucin, a triglyceride having industrially desirable properties. Work has focused on three elements in the synthetic pathway:

- the enzymology of triglyceride assembly;
- the elongases producing very long chain fatty acids;
- and carbon flux through the pathway.

Research in 1990/91

Brassica napus cells cannot insert erucic acid into the middle position of triglycerides. Another plant, *Limnanthes douglasii*, has been targeted as the source of a gene to transform *B. napus* to overcome this limitation. The enzyme was solubilized and purified several hundred fold during 1990/91.

Production of trierucin in a transformed *B. napus* requires 1,2-dierucin as a substrate for the final transacylation step. We used microspore-derived embryos of *B. napus* cv Reston as a model system to demonstrate that a transformed *B. napus* would biosynthesize the desired product, trierucin.

Erucic acid arises in cells from shorter molecules. Genetic studies of *Arabidopsis thaliana* mutants showed that chain elongation from C18 to C20 depends on at least three different enzymes. Detailed study of one mutant plant deficient in the elongation step has shown that a single nuclear gene, designated *FAE1*, controls the synthesis of very long chain fatty acids. This gene has been mapped on the *Arabidopsis* genetic map as a prerequisite to obtaining its sequence by the technique of chromosome walking.

All fatty acids are ultimately derived from acetate. We purified acetyl coenzyme A carboxylase, the rate limiting enzyme in the fatty acid synthesizing pathway, from barley leaves and showed it to be a dimer of subunit molecular mass 220 kD. A polyclonal antibody raised to the barley enzyme cross reacted with the canola enzyme and thus proved suitable for screening a *B. napus* gene library to obtain the gene sequence.

Partnerships in 1990/91

Our research has been conducted in collaboration with Keith Pomeroy (Agriculture Canada), John Ohlrogge and Chris Somerville (Michigan State University) , Drs Mukherjee and Weber (the German Federal Centre for Lipid Research) and with several other university groups in the United States and Canada.

Transgenic Plant Centre

Staff

Head of the Centre:
Dr Wilf Keller
Technical Manager:
Jerry Shyluk
Technical Officers:
Don Dymond and Delwin Epp
Guest Researchers:
Perry Aulie, Colleen Bennett, Blaine Chartrand, Mei Chen, R.K. Coldwell, Michelle Cowell, Laverne Goodman, Ma Hong, H. Kao, Cherie Koster, Mary Leggett, Michael Oelck, Elizabeth Prusinkiewicz, Jia Xie, Brent Zettl, Xuimei Zhang

The Transgenic Plant Centre is a specialized facility for propagation and testing of transgenic plants. Situated in the Kristjanson Biotechnology Complex 2 km north of the NRC building in Saskatoon, the Centre comprises 550 square metres of "transgenic"-specification greenhousing and 350 square metres of associated laboratory space. The Centre was inaugurated in February 1990 so that fiscal 1990/91 was its first full year of operation. By March 1991 the Centre reached 80% occupancy and contained more than 50 000 plants including the world's first transgenic strawberry specimens. Remarkably, not a single batch of plants was lost to system malfunctions, heat, cold or disease during the start-up year. The year saw the completion of the equipping of the facility , the elaboration of its automated and computer-controlled systems, and the establishment of sound operational procedures for the smooth functioning of the Centre.

The Centre houses some research personnel from PBI but most of the space there is kept available for use by the Institute's partner industries who need such facilities for their research. In this way NRC has enabled important advanced industrial research to go forward. The major partner companies in 1990/91 were Hoechst Canada Inc., MicroBio Rhizogen Inc., Philom Bios Inc., Prairie Plant Systems Inc. and the Saskatchewan Wheat Pool. In addition NRC maintained its strong business partnership with the Saskatchewan Economic Development Corporation, the developers of the Kristjanson Biotechnology Complex.

Jerry Shyluk and Wilf Keller examine plants at the Transgenic Plant Centre.

Business and Outreach

Head: Dr W. G. W. Kurz

The Institute has twin roles in communication of plant biotechnology information in Canada and in the management, usually through partnerships, of intellectual property and "know-how" arising from the laboratories.

PBI's business and outreach program operates through two offices, the Technology Development Office headed by Dr Wolf Kurz, and the Marketing Communications Office headed by Mrs Lorraine Blashill. This latter unit is responsible for the preparation and dissemination to the Canadian R&D community of information about the Institute and its activities. The Technology Development Office expedites technical liaison and sets up agreements for formal business interactions; these may involve the negotiation of technology licences, development of joint undertakings, advice and consultancies to firms, or the provision of research space in the Institute for companies' projects.

The Technology Development Office

The Office completed its first year of operation in 1990/91. A business strategy and targets were developed, and effective working relations were established with NRC's corporate marketing personnel and with the Council's newly-formed Intellectual Property Services Office. In addition, good relationships were formed with NRC's Industrial Research Assistance Program and with other federal and provincial agencies for technology promotion.

The targeted new business value of $480K for 1990/91 was surpassed by a wide margin even though some agreements negotiated during the year were not to take full effect until fiscal 1991/92.

The boxes at right list some major university and non-university organizations with which NRC conducted research business through the Plant Biotechnology Institute in 1990/91.

Guelph University (Guelph, ON)
Michigan State University (Lansing, MI)
McGill University (Montreal, PQ)
Université Laval (Quebec, PQ)
Université de Montréal (Montreal, PQ)
University of Alberta (Edmonton, AB)
University of British Columbia (Vancouver, BC)
University of Braunschweig (Germany)
University of Calgary (Calgary, AB)
University of California (Davis and Riverside, CA)
University of Manitoba (Winnipeg, MB)
University of Saskatchewan (Saskatoon, SK)
University of Toronto (Toronto, ON)

Agriculture Development Fund (Regina, SK)
Agriculture Canada (various establishments)
AgWest Biotech Inc (Saskatoon, SK)
Allelix Crop Technologies Inc (Mississauga, ON)
BC Research Corporation (Vancouver, BC)
Blueberry Acres Inc (Kentville, NS)
Canola Council of Canada (Winnipeg, MB)
Crop Development Centre (Saskatoon, SK)
Environment Canada (various establishments)
Esso Chemical Resources Ltd (Calgary, AB)
Forestry Canada (various establishments)
Garst Seeds Inc (Winnipeg, MB)
Heffley Reforestation Centre (Kamloops, BC)
Hoechst Canada Inc (Montreal, QB and Regina, SK)
Jiangsu Genetic Institute (Jiangsu, China)
John Innes Institute (Norwich, U. K.)
Laboratorium voor Genetika (Ghent, Belgium)
MicroBio Rhizogen Inc (Saskatoon, SK)
NeoPhyte Inc (Ottawa, ON)
Natural Sciences & Engineering Research Council
Nuvotech Inc (Saskatoon, SK)
Paladin Hybrids Inc (Brampton, ON)
Philom Bios Inc (Saskatoon, SK)
Prairie Malt Inc (Biggar, SK)
Prairie Plant Systems Inc (Saskatoon, SK)
Saskatchewan Economic Development Corp (Regina, SK)
Saskatchewan Research Council (Saskatoon, SK)
Saskatchewan Wheat Pool (Regina, SK)
Takeda Chemicals Ltd (Osaka, Japan)
Uniroyal Chemicals Ltd (Guelph, ON)
Western Economic Diversification Canada (Saskatoon, SK)
Westech Agriculture (Charlottetown, PEI)
Western Grains Research Foundation (Saskatoon, SK)
Weyerhaeuser Canada Inc (Prince Albert, SK)

The Marketing Communications Office

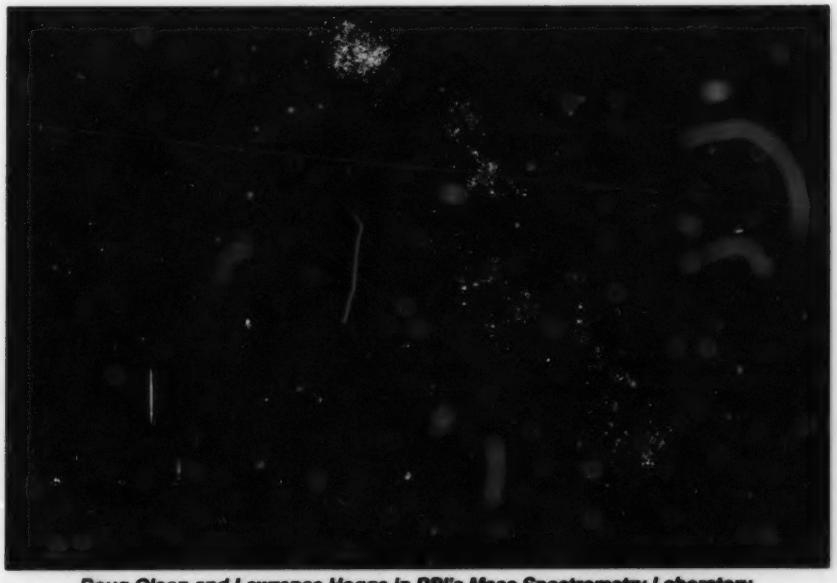
This unit successfully carried out an ambitious program of technical interpretive writing, publications, public information and special events during the year. In contrast with earlier years, much time was devoted to visits to the Institute by industry groups, and to assisting in the organization of NRC events including celebration of the Council's 75th anniversary in 1991. The principal events of the year were :

- Alberta Agricultural Research Institute meeting (30 July 1990) and visit to PBI. The AARI is Canada's largest amalgamation of ag research organizations.
- Visit to PBI of the Minister of Forestry, Hon. Frank Oberle (14 August 1990).
- Affiliated Scientists of PBI, annual meeting and symposium on plant transformation systems (5/6 September 1990).
- Workshop on Seed Oil Modification (16/17 October 1990). This Saskatoon workshop organized by PBI drew more than one hundred scientists, technical experts and business people from Canada, the United States and Europe to review the state of this fast-moving area of biotechnology.
- Visit of the President of NRC, Dr Pierre Perron (19 October 1990).
- Peer Review of the Institute (20 - 22 March 1991). This was the first part of the overall review of the NRC Biotechnology Program being carried out in 1991.

Laboratory Services

PBI provided several laboratory services to staff, to guest researchers, and to extramural clients during the year. These included:

- *DNA services*: polynucleotide strand synthesis; polynucleotide strand sequencing, polynucleotide amplification.
- *Mass spectrometry services*: high-resolution analyses; low-resolution analyses; sample preparation and separation techniques.
- *Nuclear magnetic resonance services*: analyses at 360 MHz and 90 MHz.



Doug Olson and Lawrence Hogge in PBI's Mass Spectrometry Laboratory.

Staff outreach activities, new honours and awards

The following list, though far from comprehensive or complete, indicates some of the types of outreach and recognitions occurring newly in 1990/91. A great many appointments and awards from earlier years were also being held by staff during the past year.

Dr Suzanne Abrams (Senior Research Officer) was appointed to the Board of Directors of Ag-West Biotechnology Inc.; and was appointed to the Selection Board for NRC's new Women in Science and Engineering program.

Dr Friedrich Constabel (Director of Research) was named to the NRC-Forestry Canada inter-agency steering committee.

Dr Burton Craig, the Institute's founding Director (now retired), received the Saskatchewan Order of Merit on 26 October 1990. Saskatchewan's highest decoration, this award recognized Craig's contributions to research in general and to the development of gas chromatography and the Canadian oilseed industry in particular.

Dr David Dunstan (Senior Research Officer) became Associate Editor of the research journal "In Vitro Cellular and Developmental Biology - Plant".

Dr Sean Hemmingsen (Research Officer) was invited speaker at two Gordon Conferences: "Carbon dioxide fixation in green plants" (23-27 July 1990) and "Enzyme organization and cell function" (21-25 January 1991).

Dr Shaun Hobbs (Research Officer) was an invited guest scientist at the John Innes Institute (Norwich, U.K.) through most of the year.

Dr Kutty Kartha (Senior Research Officer) became NRC's representative on the Canadian Agricultural Research Council; and gave the UNESCO course on cryopreservation of plant cells and organs in Lausanne, Switzerland (2-13 July 1990).

Dr Wilf Keller (Senior Research Officer) was appointed to the advisory boards of Agriculture Canada's Plant Research Centre in Ottawa, and Research Station in Saskatoon.

Dr John Mahon (Senior Research Officer) became the NRC representative on the Board of the Saskatchewan Crop Development Centre.

Dr Louise Nelson (Senior Research Officer) is co-chairing the organizing committee for the 13th North American Symbiotic Nitrogen Fixation Conference in Banff, Alberta.

Dr Warren Steck (Director General) received a Finalist Award in the "High-tech Entrepreneur" competition held by the Saskatchewan Advanced Technology & Manufacturing Association (26 April 1990).

Dr David Taylor (Research Officer) chaired the organizing committee for the NRC-ISTC-BioCrop joint Seed Oil Modification Workshop held in October 1990.

Dr Edward Tsang (Research Officer) was an invited researcher at the Laboratorium voor Genetika in Ghent, Belgium, throughout part of the year.

Dr Edward Underhill (Principal Research Officer) received the Doctor of Science degree from the University of Saskatchewan at Fall Convocation, 27 October 1990, in recognition of his outstanding contributions in the fields of plant biochemistry and insect pheromone technology.

In addition to the above new recognitions and activities, staff of the Institute received invitations to give more than two hundred invited lectures, received requests to review more than one hundred applications for research funding, and were active participants in fifty-two scientific societies and associations. Some staff gave university lecture courses in 1990/91 by invitation.

1990/91 Seminar Series

06 April 90: **Dr. Atanas Atanassov** (Institute of Genetic Engineering, Agricultural Academy, Bulgaria): **Research activities in the Institute of Genetic Engineering, Agricultural Academy**

18 April 90: **Dr. Michael Dixon** (Dept. of Horticultural Science, University of Guelph): **Plants as environmental sensors**

25 April 90: **Dr. Brenda McAfee** (NRC, Plant Biotechnology Institute, Saskatoon): **Rooting of conifers using microorganisms**

16 August 90: **Dr. Shozo Takahashi** (Pesticide Research Institute, Kyoto University): **Host finding behavior of parasitoid wasps**

20 August 90: **Dr. Otto Schieder** (Dept. Botany, Free University of Berlin): **Asymmetric hybridization and transformation in higher plants**

10 September 90: **Dr. Elizabeth Weretilnyk** (Dept. Biology, McMaster University, Hamilton, Ontario): **Betaine aldehyde dehyrogenase: Biochemical and genetic analysis of an enzyme implicated in the adaptation of higher plants to drought and salinity**

20 September 90: **Dr. Günther Donn** (Hoechst AG, Frankfurt, Germany.): **Production of fertile transgenic maize via direct gene transfer into protoplasts**

21 September 90: **Paul Arnison** (General Manager, Paladin Hybrids, Brampton, Ontario): **Molecular approaches to hybrid seed production**

26 September 90: **Dr. Adrian Cutler** (NRC, Plant Biotechnology Institute, Saskatoon): **Mitotic re-initiation in cultured plant protoplasts**

17 October 90: **Dr. Elizabeth D. Earle** (Dept. Plant Breeding, Cornell University, Ithaca, NY): **Novel Brassica plants from protoplast culture and fusion**

24 October 90:**Dr. Benoit S. Landry** (Agriculture Canada, St. Jean-sur-Richelieu, PQ): **RFLP analyses of the Brassica genome**

07 November 90: **Dr. Ed Tsang** (NRC, Plant Biotechnology Institute, Saskatoon): **Superoxide dismutase genes**

14 November 90: **Dr. Janet Taylor** (NRC, Plant Biotechnology Institute, Saskatoon): **Electrophoretic separation of large molecular weight DNA**

21 November 90: **Dr. Michael M. Oelck** (Hoechst Canada Ltd., Saskatoon): **Transformation of *Brassica napus* including results of field tests**

28 November 90: **Dr. Faouzi Bekkaoui** (NRC, Plant Biotechnology Institute, Saskatoon): **mRNA quantitation by the polymerase chain reaction; application to acetolactate synthase**

03 December 90: **Dr. Brian Fristensky** (Dept. of Plant Science, University of Manitoba, Winnipeg): **Regulation and evolution of disease resistance response genes in plants**

05 December 90: **Dr. David J. Gifford** (Dept. of Botany, University of Alberta, Edmonton): **Developmental regulation of gene expression during stratification and germination of gymnosperms: a seedy story**

07 December 90: **Dr. Karin Nichterlein** (University of Giessen, Germany): **Overview of oilseed tissue culture research at the Plant Breeding Institute, University of Giessen, Germany**

13 December 90: **Dr. Clifford Hunter** (Garst Research Limited, Slater, Iowa): **Plant regeneration from microspores of barley for breeding and towards transformation**

19 December 90: **Dr. Bryan D. McKersie** (Dept. of Crop Science, University of Guelph): **Desiccation of somatic embryos for production of artificial seeds**

09 January 91: **Dr. Indra K. Vasil** (University of Florida): **Regeneration and genetic transformation of wheat**

06 February 91: **Dr. Gerhard Rakow** (Agriculture Canada, Saskatoon): **Breeding new canola cultivars**

20 February 91: **Dr. Carl Douglas** (Dept. of Botany, University of B.C., Vancouver): **Developmental and stress regulation of phenylpropanoid genes in hybrid poplar and transgenic tobacco**

13 March 91: **Dr. Anne Johnson-Flanagan** (University of Alberta, Edmonton): **The effect of frost on canola seed development**

28 March 91: **Dr. Mark Jordan** (NRC, Plant Biotechnology Institute, Saskatoon): **A Stab in the Dark - Genetic Transformation in Pea**

Management and Administration

Joan L. Yorke, Administrative Manager

The management and administration of the Institute underwent several changes during the year 1990/91. The office of Director of Research, set up in 1989/90, was formalized and Dr Fred Constabel became responsible in that capacity for implementing PBI's annual research plans effectively. The Research Director took over the chairmanship of the Institute's Planning and Review Committee, and this group grew with the setting up early in the year of Cold Tolerance Genes as a separate project group. As an internal policy advice body for the Director General , a small group of senior managers was set up to meet regularly. PBI took part fully in the general clarification of management functions that occurred during the year throughout NRC.

March 1991 saw retirements of several senior administrative staff, including the Institute's Administrative Manager (Joan L. Yorke), the Superintendent of Building Services (T. Martin Mallard) and the Supply Officer (James McHarg), whose expertise will be much missed. In the same month, the Institute began both its examination under NRC's review of the Biotechnology Program, and its celebration of the Council's seventy-fifth anniversary whose events will extend through 1991.

In the realm of facilities renovation, 1990/91 brought less activity than usual because of financial constraints. A new laboratory unit for organic chemistry was completed and commissioned, and plans were carried forward for major exterior repairs which must be undertaken later in 1991. The growth chamber array for plant and cell growth was increased by the addition of two new units.

Committees

Five committees of the Institute provide liaison between users and providers of key services to programs, or permit collegial planning and cooperation among PBI groups.

The **Planning & Review Committee** is the premier PBI committee, consisting of managers and all research group leaders. Members in 1990/91 were Suzanne Abrams, Fred Constabel (chair), Adrian Cutler, David Dunstan, Sean Hemmingsen, Kutty Kartha, Wilf Keller, Samuel MacKenzie, John Mahon, Gopalan Selvaraj, Warren Steck (ex-officio) and Joan Yorke. Secretary was Rosemarie Gallays.

Computer Committee: The group's role is to advise on future needs for computer systems. Members at year end were: Cheryl Bock, Brock Chatson, Adrian Cutler, Sean Hemmingsen, Harry Holfeld, Mark Jordan, Samuel MacKenzie, Martin Mallard (chair).

Library Committee: This committee assists the on-site plant biotechnology branch of the Canada Institute for Scientific and Technical Information (CISTI) in choosing book and journal orders which match current project needs in the Institute. Members are year end were: John Balsevich, Flora Chen (chair), Ravi Chibbar, Bill Crosby, Ljerka Kunst, Victor Morales, Edward Tsang.

Special Events Committee: This committee assisted with the organization and carrying out of major tours, workshops and exposition events during the year. Members at year end were: Lorraine Blashill (chair), Karen Caswell, Maxine Coffey, Rozina Hirji, Connie Knapp, Doug Olson, Darwin Reed.

Safety and Health Committee: The group is part of NRC's overall organizational network for workplace safety and health. It advises on potential risks, and has responsibilities in hazards procedures and in first aid training for staff. Members at year-end were: Terry Bethune, Janet Condie, Brock Chatson, Martin Mallard, David Taylor (co-chair), Janet Taylor, Joan Yorke, John Magus.

Publications in 1990

These are the research publications, authored or co-authored by staff members of the Plant Biotechnology Institute, which appeared in print in 1990.

1. Abrams, G.D., S.R. Abrams, L.A.K. Nelson and L.V. Gusta. 1990. **Total synthesis of (±)-phaseic acid**. Tetrahedron 46: 5543-5554. NRCC No. 31230.

2. Adams, R.P., E. Kendall and K.K. Kartha. 1990. **Comparison of free sugars in growing and desiccated plants of *Selaginella lepidophylla***. Biochemical Systematics and Ecology 18: 107-110. NRCC No. 30915.

3. Arnison, P.G. and W.A. Keller. 1990. **A survey of the anther culture response of *Brassica oleracea* L. cultivars grown under field conditions**. Plant Breeding 104: 125-133.

4. Arnison, P.G., P. Donaldson, L.C.C. Ho and W.A. Keller. 1990. **The influence of various physical parameters on anther culture of broccoli (*Brassica oleracea* var italica)**. Plant Cell Tissue and Organ Culture 20: 147-155.

5. Arnison, P.G., P. Donaldson, A. Jackson, C. Semple and W.A. Keller. 1990. **Genotype-specific response of cultured broccoli (*Brassica oleracea* var italica)**. Plant Cell Tissue and Organ Culture 20: 217-222.

6. Archambault, J., B. Volesky and W.G.W. Kurz. 1990. **Development of bioreactors for the culture of surface immobilized plant cells**. Biotechnology and Bioengineering 35: 702-711.

7. Archambault, J., B. Volesky and W.G.W. Kurz. 1990. **Production of indole alkaloids by surface immobilized *Catharanthus roseus* cells**. Biotechnology and Bioengineering 35: 660-667.

8. Attree, S., D.I. Dunstan and L.C. Fowke. 1990. **Plantlet regeneration from embryogenic protoplasts of white spruce (*Picea glauca*)**. Biotechnology 7: 1061-1063. NRCC No. 31222.

9. Bekkaoui, F., R.S.S. Datla, M. Pilon, T.E. Tautorus, W.L. Crosby and D.I. Dunstan. 1990. **The effects of promoter on transient expression in conifer cell lines**. Theoretical and Applied Genetics 79: 353-359. NRCC No. 30498.

10. Blake, T.J., W. Tan and S.R. Abrams. 1990 **Anti-transpirant action of abscisic acid and ten synthetic analogs in black spruce**. Physiologia Plantarum 80: 365-370.

11. Blake, T.J., E. Bevilacqua, G.A. Hunt and S.R. Abrams. 1990. **Effects of abscisic acid and its acetylenic alcohol on dormancy, root development and transpiration in three conifer species**. Physiologia Plantarum 80: 371-378.

12. Boyle, S.A., S.M. Hemmingsen and D.T. Dennis. 1990. **Energy requirement for the import of protein into plastids from developing endosperm of *Ricinus communis* L.** Plant Physiology 92: 151-154.

13. Bremer, E., C. Van Kessel, L. Nelson, R. Rennie, and D. Rennie. 1990. **Selection of *Rhizobium leguminosarum* strains for lentil (*Lens culinaris*) under growth room and field conditions**. Plant and Soil 121: 47-56.

14. Carlisle, S.M., S.D. Blakeley, S.M. Hemmingsen, D.T. Dennis, S.J. Travanion, T. Hiyoshi and N.J. Kruger. 1990. **Pyrophosphate dependent phosphofructokinase: conservation of protein sequence between the alpha and beta subunits and with the ATP dependent phosphofructokinase**. Journal of Biological Chemistry 265: 18366-18371.

15. Carolis, E.D., F. Chan, J. Balsevich and V. DeLuca. 1990. **Isolation and characterization of a 2 -oxoglutarate dependent dioxygenase involved in the second-to-last step in vindoline biosynthesis**. Plant Physiology 94: 1323-1329. NRCC No. 32454.

16. Chanway, C.P. and L.M. Nelson. 1990. **Field and laboratory studies of *Triticum aestivum* L. inoculated with co-existent growth-promoting Bacillus strains**. Soil Biology and Biochemistry 22: 789-795. NRCC No. 30917.

17. Chibbar, R.N., K.K. Kartha, N. Leung, F. Georges, K. Caswell, J. Qureshi, C. Mallard and E. Kendall. 1990. **Microprojectile mediated delivery of marker genes and their expression in *in vitro* cultures and immature zygotic embryos of wheat and barley**. Journal of Cellular Biochemistry (supplement) 14E: 277.

18. Chevrier, N., J.A. Qureshi, P. Hucl and K. Kartha. 1990. **Heritability of in vitro regeneration in wheat (*Triticum aestivum* L.)**. Canadian Journal of Plant Science 70: 547-550. NRCC No. 31225.

19. Constabel, F. 1990. **Medicinal plant biotechnology**. Planta Medica 56: 421-492. NRCC No. 31487.

20. Datla, R.S.S., J.K. Hammerlindl, L.E. Pelcher, G. Selvaraj and W.L. Crosby. 1990. **A bifunctional gene fusion between neomycin phospho-transferase and beta-glucuronidase: a broad spectrum genetic marker for plants**. Journal of Cellular Biochemistry (supplement) 14E: 279.

21. Dunstan, D.I. 1990. **Introduction.** Canadian Journal of Forest Research 19: 1297-1298. NRCC No. 30494.

22. Dunstan, D.I. and M.S. Lapp. 1990. **Toward the *in vitro* propagation of three Canadian conifer species**. Pulp and Paper Canada 91: 419-421. NRCC No. 30496.

23. Georges, F., M. Saleem and A.J. Cutler. 1990. **Design and cloning of a synthetic gene for the flounder antifreeze protein and its expression in plant cells**. Gene 91: 159-165. NRCC No. 30705.

24. Good, A.G., F. Bekkaoui, G. Pilate, D.I. Dunstan and W.L. Crosby. 1990. **Anaerobic induction in conifers: Expression of endogenous and chimeric anaerobically-induced genes.** Physiologia Plantarum 78: 441-446. NRCC No. 30260.

25. GrootWassink, J.W.D., J.J. Balsevich and A.D. Kolenovsky. 1990. **Formation of sulfatoglucosides from exogenous aldoximes in plant cell cultures and organs.** Plant Science 66: 11-20. NRCC No. 31231.

26. Hemmingsen, S.M. 1990. **The plastid chaperonin.** Seminars in Cell Biology 1: 47-54. W.B. Saunders Co., Philadelphia.

27. Hobbs, S.L.A., J.A. Jackson, D.S. Baliski, C.M.O. DeLong and J.D. Mahon. 1990. **Genotype- and promoter-induced variability in transient beta-glucuronidase expression in pea protoplasts.** Plant Cell Reports 9: 17-20.

28. Hobbs, S.L.A., L.E. Pelcher, C.M.O. DeLong, M. Anderson and J.D. Mahon. 1990. **Genetic variability in the amount of ribulose-1, 5-bisphosphate carboxylase/oxygenase and its small subunit mRNA in pea.** Planta 180: 510-516.

29. Hobbs, S.L.A., P. Kpodar and C.M.O. DeLong. 1990. **The effect of T-DNA copy, number, position and methylation on reporter gene expression in tobacco transformants.** Plant Molecular Biology 15: 851-864. NRCC No. 31495.

30. Huang, B., S. Bird, R. Kemble, D. Simmonds, W. Keller and B. Miki. 1990. **Effects of culture density, conditioned medium and feeder culture on microspore embryogenesis in *Brassica napus* L. cv Topas.** Plant Cell Reports 8: 594-597.

31. Hudson, G.S., J.D. Mahon, P.A. Anderson, M.J. Gibbs, M.R. Badger, T.J. Andrews and P.R. Whitfeld. 1990. **Comparisons of rbcL genes for the large subunit of ribulose-bisphosphate carboxylase from closely related C4 plant species.** Journal of Biological Chemistry 265: 808-814.

32. Hynes, R.K. and L.M. Nelson. 1990. **Interactions among nitrogen-transforming bacteria and nitrogen-fixing *Pisum sativum* L. in laboratory sand columns.** Plant and Soil 122: 157- 167. NRCC No. 30707.

33. Jackson, J.A. and S.L.A. Hobbs 1990. **Rapid multiple shoot production from cotyledonary node explants of pea (*Pisum sativum* L.).** In vitro Cellular and Developmental Biology 26: 835-838. NRCC No. 31226.

34. Jain, J.C., J.W.D. GrootWassink, A.D. Kolenovsky and E.W. Underhill. 1990. **Purification and properties of 3'-phosphoadenosine-5'- phosphosuphate: desulphoglucosinolate sulphotransferase from *Brassica juncea* cell cultures.** Phytochemistry 29: 1425-1429. NRCC No. 30495.

35. Jain, J.C., J.W.D. GrootWassink, D.W. Reed and E.W. Underhill. 1990. **Persistent co-purification of enzymes catalyzing the sequential glucosylation and sulfation steps in glucosinolate biosynthesis.** Journal of Plant Physiology 136: 356-361.

36. Joseph, O.O., S.L.A. Hobbs and S. Jana. 1990. **Diclofop resistance in wild oat (*Avena fatua*).** Weed Science 38: 475-479. NRCC No. 31486.

37. Kao, H.M., W.A. Keller, S. Gleddie and G.G. Brown. 1990. **Efficient plant regeneration from hypocotyl protoplasts of broccoli, *Brassica oleracea*.** Plant Cell Reports 9: 311-315.

38. Kapur, R., A.J. Cutler, M. Saleem and B.L. Harvey. 1990. **Oxidative stress in barley leaf protoplasts may be related to their recalcitrance.** In vitro 26: 73A.

39. Kartha, K.K., R.N. Chibbar, F. Georges, N. Leung, K. Caswell, E. Kendall and J. Qureshi. 1990. **Transient expression of chloramphenicol acetyltransferase (CAT) gene in barley cell cultures and immature embryos through microprojectile bombardment.** Plant Cell Reports 8: 429-432. NRCC No. 30706.

40. Kendall, E., R. Adams and K.K. Kartha. 1990. **Trehalase activity in plant tissue cultures.** Phytochemistry 29: 2525-2528. NRCC No. 31229.

41. Kendall, E.J., K.K. Kartha, N. Chevier, T.H.H. Chen, J.A. Qureshi, N. Leung and K. Caswell. 1990. **Regeneration of freezing-tolerant spring wheat (*Triticum aestivum* L.) plant from cryoselected callus.** Plant Physiology 94: 1756-1762. NRCC No. 31493.

42. Kunst, L. and E.W. Underhill. 1990. **Cloning fae1, a gene which controls fatty acid elongation in seeds of *Arabidopsis thaliana*, by chromosome walking.** Proceedings of the Sixth Crucifer Genetics Workshop, October 6-9, 1990, Cornell University.

43. Kurz, W.G.W., N.L. Paiva and R.R. Tyler. 1990. **Biosynthesis of sanguinarine by elicitation of surface immobilized cells of *Papaver somniferum* L.** Proceedings of the VII International Congress on Plant Tissue and Cell Culture, Amsterdam, 24-29 June 1990, Netherlands. Eds. H.J.J. Nijkamp, L.H.W. van der Plas and J. van Aartrijk. pp. 682-688.

44. Lam, K.S. and J.W.D. GrootWassink. 1990. **Enzymatic digestion of spent yeast cells for nutrient recycling in inulase production.** Journal of Industrial Microbiology 6: 207-210.

45. Lamb, N. and S. Abrams. 1990. **Synthesis of optically active cyclohexanone analogs of the plant hormone abscisic acid.** Canadian Journal of Chemistry 68: 1151-1162.

46. MacKenzie, S.L. and D.C. Taylor. 1990. **Analysis of fatty acyl CoA esters by capillary electrophoresis.** In: Plant Lipid Biochemistry, Structure and Utilization. Eds. P.J. Quinn and J.L. Harwood. Portland Press Ltd. pp 27-29.

47. MacKenzie, S.L. 1990. **Amino Acids.** In: Gas Chromatography: Biochemical, Biomedical and Clinical Applications. Ed. R.E. Clement. John Wiley and Sons, New York. Chapter 10, pp 267-293.

48. Mahon, J. 1990. **Photosynthesis and crop productivity**. In: Perspectives in Biochemical and Genetic Regulation of Photosynthesis. Alan R. Liss, Inc. pp. 379-394. NRCC No. 30708.

49. Mahon, J. 1990. **Photosynthetic carbon dioxide exchange, leaf area, and growth of field-grown pea genotypes**. Crop Science 30: 1093-1098. NRCC No. 31498.

50. Martel, R., L.P. Cloney, L.E. Pelcher and S.M. Hemmingsen. 1990. **Unique composition of plastid chaperonin-60: alpha and beta polypeptide-encoding genes are highly divergent**. Gene 94: 181-187. NRCC No. 31490.

51. Millar, J.G., M. Giblin, D. Barton and E.W. Underhill. 1990. **(3Z,6Z,9Z)-Nonadeca-triene and enantiomers of (3Z,9Z)-cis-6,7-epoxy-nonadecadiene as sex attractants for two geometrid and one noctuid moth species**. Journal of Chemical Ecology 16: 2153-2166. NRCC No. 30266.

52. Millar, J.G., M. Giblin, D. Barton, A. Morrison and E.W. Underhill. 1990. **Synthesis and field testing of enantiomers of 6Z,9Z-cis-3,4-epoxydienes as sex attractants for geometrid moths**. Journal of Chemical Ecology 16: 2317-2339.

53. Millar, J.G., M. Giblin, D. Barton, D.A. Reynar, G.B. Neill and E.W. Underhill. 1990. **Identification and field testing of female-produced sex pheromone components of the spring cankerworm, *Paleacrita vernata* Peck (Lepidoptera: Geometridae).** Journal of Chemical Ecology 16: 3393-3409. NRCC No. 30711.

54. Nehra, N.S., R.N. Chibbar, K.K. Kartha, R.S.S. Datla, W.L. Crosby and C. Stushnoff. 1990. ***Agrobacterium*-mediated transformation of strawberry calli and recovery of transgenic plants**. Plant Cell Reports 9: 10-13. NRCC No. 31227.

55. Nehra, N.S., C. Stushnoff and K.K. Kartha. 1990. **Regeneration of plants from immature leaf-derived callus of strawberry (*Fragaria* x *ananassa*).** Plant Science 66: 119-126. NRCC No. 30500.

56. Nehra, N.S., R.N. Chibbar, K.K. Kartha, R.S.S. Datla, W.L. Crosby and C. Stushnoff. 1990. **Genetic transformation of strawberry by *Agrobacterium tumefaciens* using a leaf disk regeneration system**. Plant Cell Reports 9: 293-298. NRCC No. 31491.

57. Nehra, N.S., R.N. Chibbar, K.K. Kartha, R.S.S. Datla, W.L. Crosby and C. Stushnoff. 1990. **Genetic transformation of strawberry by *Agrobacterium tumefaciens* using a leaf disc regeneration system**. Journal of Cellular Biochemistry (supplement) 14E: 287.

58. Nessler, C.L., W.G.W. Kurz and L.E. Pelcher. **Isolation and analysis of the major latex protein genes of opium poppy**. Plant Molecular Biology 15: 951-953. NRCC No. 32443.

59. Orr, W., A.M. Johnson-Flanagan, W.A. Keller and J. Singh. 1990. **Induction of freezing tolerance in microspore-derived embryos of winter *Brassica napus***. Plant Cell Reports 8: 579-581.

60. Orshinsky, B.R., L.J. McGregor, G.I.E. Johnson, P. Hucl and K.K. Kartha. 1990. **Improved embryoid induction and green shoot regeneration from wheat anthers cultured in medium with maltose**. Plant Cell Reports 9: 365-369. NRCC No. 31494.

61. Pedras, M.S.C., G. Seguin-Swartz and S. Abrams. 1990. **Minor phytotoxins from the blackleg fungus *Phoma lingam***. Phytochemistry 29: 777-782. NRCC No. 30713.

62. Pedras, M.S.C. and G. Seguin-Swartz. 1990. **Rapid high-performance liquid chromatographic analysis of phytotoxins from *Phoma lingam***. Journal of Chromatography 519: 383-386. NRCC No. 32448.

63. Penner, G.A. and G. Selvaraj. 1990. **Salt and polyethylene glycol inducible polypeptides in a dicotyledonous halophyte *Kochia scoparia* L. (Schrad)**. Plant Physiology 93: 6.

64. Pivnick, K.A., B.J. Jarvis, G.P. Slater, C. Gillott and E.W. Underhill. 1990. **Attraction of the diamondback moth (Lepidoptera: Plutellidae) to volatiles of oriental mustard: the influence of age, sex and prior exposure to mates and host plants**. Environmental Entomology 19: 704-709. NRCC No. 30704.

65. Pivnick, K.A., B.J. Jarvis, G.P. Slater, C. Gillott and E.W. Underhill. 1990. **Daily patterns of reproductive activity and the influence of adult density and exposure to host plants on reproduction in the diamondback moth (Lepidoptera: Plutellidae)**. Environmental Entomology 19: 587-593.

66. Powers, R., W.G.W. Kurz and V. DeLuca. 1990. **Purification and characterization of acetylcoenzyme A: deacetylvindoline 4-O-acetyltransferase from *Catharanthus roseus***. Archives of Biochemistry and Biophysics 279: 370-376.

67. Rossnagel, B.G., K.N. Kao and J.A. Weller. 1990. **Rapid transfer of spot-form net blotch resistance from six-row to two-row barley via anther culture and field performance of the resulting genotypes.** [Abstract for 14th American Barley Workshop, Davis, California,U.S.A.] Barley Newsletter 33: 107.

68. Rozwadowski, K.L., G.G. Khachatourians and G. Selvaraj. 1990. **Choline oxidase, a catabolic enzyme in *Arthrobacter pascens*, facilitates adaptation to osmotic stress in Escherichia coli**. Journal of Bacteriology. 173: 472-478. NRCC No. 32463.

69. Saxena, P.K., J.K. Hammerlindl, W.L. Crosby and J. King. 1990. **Introduction of resistance to kanamycin into an auxotrophic cell culture of *Datura innoxia* following direct-gene transfer**. Plant Science 70: 105-114.

70. Songstad, D.D., V. DeLuca, N. Brisson, W.G.W. Kurz and C.L. Nessler. 1990. **High levels of tryptamine decarboxylase**. Plant Physiology 94: 1410-1413. NRCC No. 31492.

71. Taylor, D., N. Weber, L. Hogge and E. Underhill. 1990. **A simple enzymatic method for the preparation of radiolabeled erucoyl-CoA and other long chain fatty acyl-CoAs and their characterization by mass spectrometry**. Analytical Biochemistry 184: 311-316. NRCC No. 30908.

72. Taylor, D.C., N. Weber, E.W. Underhill, M.K. Pomeroy, W.A. Keller, W.R. Scowcroft, R.W. Wilen, M.M. Moloney and L.A. Holbrook. 1990. **Storage-protein regulation and lipid accumulation in microspore embryos of *Brassica napus* L.** Planta 181: 18-26. NRCC No. 31224.

73. Taylor, D.C., N.Weber, D. Barton, E.W. Underhill and K. Pomeroy. 1990. **Biosynthesis of triacylglycerols containing erucic acid in microspore-derived embryos of *Brassica napus***. In: Plant Lipid Biochemistry, Structure and Utilization. Eds. P.J. Quinn and J.L. Harwood. Portland Press Ltd. pp 210-212.

74. Tautorus, T., S.M. Attree, L.C. Fowke and D.I. Dunstan. 1990. **Somatic embryogenesis from immature and mature zygotic embryos, and embryo regeneration from protoplasts in black spruce (*Picea mariana* Mill)**. Plant Science 67: 115-124. NRCC No. 30264.

75. Tautorus, T.E., L.C. Fowke and D.I. Dunstan. 1990. **Comparative studies of protoplast development in jack pine (*Pinus banksiana*)**. Canadian Journal of Botany 68: 1774-1779. NRCC No. 30913.

76. Tulloch, A.P. 1990. **Glycosides of hydroxy fatty acids**. In: Glycolipids, Phosphoglycolipids and Sulfoglycolipids. Ed. Morris Kates. Plenum Publishing Corporation. Chapter 6, pp 463-487.

77. Van Camp, W., C. Bowler, R. Villarroel, E.W.T. Tsang, M. Van Montagu and D. Inzé. 1990. **Characterization of an iron superoxide dismutase cDNA from plants obtained by genetic selection in *Escherichia coli***. Proceedings of the National Academy of Sciences 87: 9903-9907.

78. Wiersma, P.A., D.L. Durda, I. Babic, W.L. Crosby and M.M. Moloney. 1990. ***In vivo* and *in vitro* mutagenesis of a *Brassica napus* acetolactate synthase gene for the production of herbicide resistance.** In: Progress in Plant, Cellular and Molecular Biology. Eds. H.J.J. Nijkamp, L.H.W. Van der Plas and J. Van Aartrijk. Kluwer Academic Publishers, Bordrecht, pp 157-162.

79. Wiersma, P.A., J. Hachey, W.L. Crosby and M.M. Moloney. 1990. **Specific truncations of an acetolactate synthase gene from *Brassica napus* efficiently complement ilvB/ilvG mutants in *Salmonella typhymurium***. Molecular and General Genetics 224: 155-159.

80. Wiersma, P.A., J. Hachey, W.L. Crosby and M.M. Moloney. 1990. **Efficient complementation of acetohydroxyacid synthase (AHAS) deficient bacteria by a modified *Brassica napus* AHAS gene.** Journal of Cell Biochemistry (supplement) 14E: 343.

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Dr. Lloyd A.K. Nelson, NSERC
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Ms. Laurel O'Connor, Philom Bios Inc
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Ms. Elizabeth Orysubuiewicz, Philom Bios Inc
Dr. Brian Orshinsky, Saskatchewan Wheat Pool

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Associated Laboratory: The Forest Biotechnology Centre of BC Research Corporation (3650 Wesbrook Mall, UBC Campus, Vancouver)

Director of the Centre:
Ben Sutton, B.Sc., M.Sc., Ph.D. (British Columbia)

The Forest Biotechnology centre (FBC) became an associated laboratory of the NRC in the spring of 1990. The Centre, established in 1987 in order to apply biotechnology to the problems of reforestation and tree improvement, conducts research in four areas: molecular genetics, tissue culture, microbial inoculants and ecophysiology.

FBC applies recombinant DNA techniques to the analysis of wild populations and selected trees in tree breeding programs. This information can be used in measuring hybridization and in selecting seed sources appropriate for areas to be reforested. Our tissue culture research accelerates the introduction of improved seed through effective mass propagation techniques and to the development of clonal forestry. Microbial inoculants research isolates strains which can provide disease control and root growth promotion of conifer seedlings. At FBC the principles of ecophysiology are being applied to assess seedling quality in existing and modified seedling production protocols.

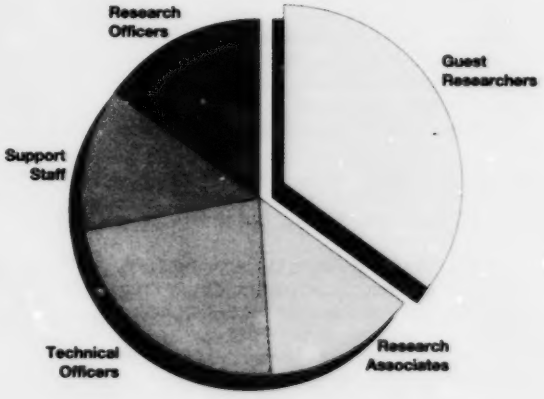
Conifer somatic embryogenesis shows considerable promise as a means of mass propagation of trees for reforestation purposes. The FBC's project with the National Research Council draws together expertise at BC Research Corp., the NRC Plant Biotechnology Institute and Forestry Canada's Petawawa National Forestry Institute. The project's main goal is to test mass cloning and propagation of plants ("emblings") generated from somatic embryos of interior spruce in nursery and field evaluations. An additional goal of the project is to develop new protocols for efficient production of high quality emblings for use in reforestation.

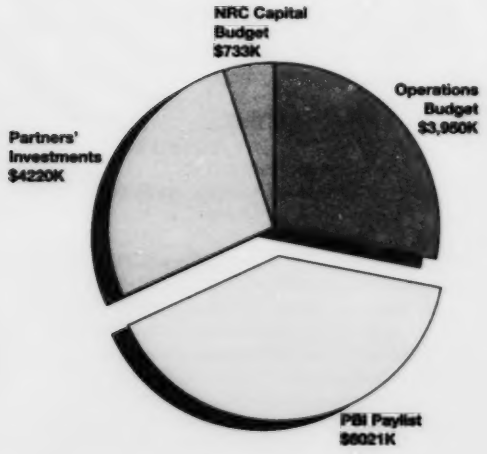
During 1990/91 the project established emblings in several field trials in British Columbia. Physiological and morphological monitoring of the emblings at various stages of development is ongoing. Isozyme screenings carried out by the Petawawa National Forestry Institute showed that the frequencies of somaclonal variation were below detectable levels. By integrating the expertise of PBI and BC Research the regeneration capacity of embryogenic cell cultures has been improved markedly.

Canada's Investment at PBI

The Plant Biotechnology Institute is the site of research activities funded by both public and private purses. During 1990/91 the federal government's support totalled $10.5 million including a one-time paylist item of $0.4 million. This compared with $10.5 million in the previous fiscal year. Private sector sources including universities funded an additional $4.2 million worth of on-site activities, an increase of more than 25% over last year's external investment total of $3.2 million. The diagrams below summarize how staff and financial resources were allocated and expended at PBI during 1990/91.

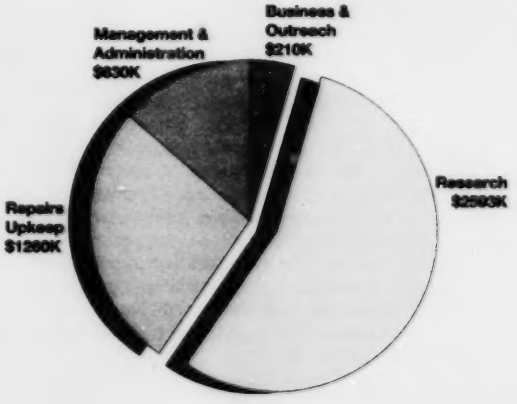
Staff resources: *NRC provided 107 person-years of labour in the four categories shown, and external funding supported 58 person-years of guest research work.*





Financial resources: *NRC provided $10.7 million including $0.2 million received as fees for services to external clients. Partners' contributions to work at the Institute amounted to $4.22 million.*

Expenditure areas: *This shows NRC non-paylist resources only. The research program expenditures of $2.593 million stood at the lowest level ever (55%) relative to all expenditures ($4.7 million). Overall expenses were down 8% from 1989/90's total of $5.1 million.*



The Year Ahead: 1991/92

The Plant Biotechnology Institute faces three principal challenges in 1991/92. On the scientific side the momentum built up in recent years in the area of transgenic plant generation and assessment must be maintained. As transformation and plant regeneration techniques are brought to high efficiency our groups will become more involved in identification of useful genes for insertion into crop plants, and in devising means for controlling the regulation of gene activities in host plants. By 1992 we'll demonstrate several new specimen transgenic plant types in our greenhouses, and expect to possess many novel DNA regulatory sequences.

On the business side our challenge is again to increase our partnerships in fulfilment of NRC's plans for increasing "levered" R & D investments outside the Council itself. We look forward especially to increased industrial partnerships with major firms.

Our operations structure will be reviewed and renewed in 1991/92 as a result of a major examination by NRC of its biotechnology program, and because of retirement of several senior operations staff. Without doubt, human resources training will assume higher priority in the years ahead.

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